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Speech Science Research Centre

# **The phonetics-phonology overlap**

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# The Phonetics Phonology Overlap

James M Scobbie

## 1 Border disputes, political and topographical

The concept of an interface in linguistics implies a connection between two distinct theoretical domains, each concerned with a distinct group of linguistic phenomena. If the domains or phenomena are very different, the purpose and nature of an interface in the theory is to state (explicitly and without redundancy) any necessary connections between what would otherwise be independent aspects of the grammar. On the other hand, if the domains or phenomena have numerous similarities, the interface is additionally characterised by theoretical competition between descriptions of and explanations for particular phenomena. In this situation, linguistic data are thought to be capable of providing evidence for particular theories of modular demarcation. Signature phenomena acquire the status of being theoretically crucial puzzles, and if generally acceptable solutions are found, they define the watershed for a generation of researchers until better data, broader research questions or theoretical innovations come along to disrupt the consensus.

The phonetics/phonology interface is very much of this confrontational type. There is a pressure to circumscribe, describe and explain any a priori “phenomenon” in the sound system theoretically from *either* a phonetic *or* a phonological perspective. Therefore, both descriptive and theoretical research converge precisely on those phenomena which cannot easily be apportioned. Consequently the literature is dense with competing theoretical proposals for what, despite some variation, are labeled as the “same” phenomena. Some research may explicitly evaluate the evidence that a phenomenon should belong discretely to one module rather than the other, even in the situation where the phenomenon itself is somewhat nebulous. More commonly, phenomena recur as topics for re-analysis within one domain or the other, where the goal is to remove any arbitrary stipulations needed in previous theories, without typically calling the modular affiliation of the phenomenon into question. And as for splitting the behaviour in question between phonetics and phonology as a solution to those arbitrary stipulations — this is thought either to deny the phenomenon’s existence as a homogenous entity or to redundantly duplicate the analysis.

An increasing number of phoneticians and phonologists have taken the phonetically-grounded character of some indisputably phonological phenomena (such as categorical assimilation or lenition) as a signal that only fresh phonetically-oriented empirical and theoretical research can hope to resolve these boundary disputes, thereby enabling more satisfying explanations for the underlying systems. In fact, finer-grained data can also add to our problems. Phonetically-detailed studies of multiple speakers reveal how great is the extent of language-specific control of phonetic targets (often resulting in subtle interspeaker variation) in phenomena that are firmly within the phonological canon. Such work shows the extent to which subtle,

gradient and variable (i.e. phonetic) patterns exist alongside the gross and categorical (i.e. phonological) ones that have previously been easily detected via native speaker intuition and impressionistic transcription of individuals or small homogenous groups of speakers. My feeling is that an increased rate of phonetically sophisticated research will uncover more cases of such parallelism as well as adding phonetic detail to uncontroversial phonological patterns.

Of course, even broad impressionistic data can reveal parallels between patently contrastive and non-contrastive phenomena. The topic was perhaps most influentially discussed by Halle (1959), and thereafter, to some extent, regarded by many phonologists as a problem solved: homogenous phenomena should not be split across modules. Consequently, in most generative phonology, surface structure is specific enough to enable the representation of a great deal of redundancy, with a consequential emphasis in phonology towards the rules that govern it. Even a radical increase in the theoretical importance of constraints on surface representation has not yet been reflected in any deep concern over the complete lack of any scientific basis or objective definition as to which phenomena should, and which should not, be represented at all in surface structure. To put it as a question: what counts as phonological data? What gets into surface structure in the first place? The presence of some types of allophonic variation in surface structure will require different theories of constraints and constraint interaction than others. But despite the fact that phonological theory is utterly dependent on the inclusion or exclusion of particular phenomena from the set of relevant data (because capturing certain patterns may require extensions to the expressive power of the formalism), the main reawakening of interest in the theoretical importance of the interface to phonology has come, it seems to me, from the relatively small number of researchers who are interested in understanding quantitative phonetic data or whose interest has been the interface in its own right. Yet if the surface representations which phonological theory aims to generate are arbitrary, idealised, and at the whim of the phonologist, then the repercussions for phonology extend far beyond the merely substantive issue of whether some low-level phenomenon is given an analysis or not. For surface-oriented phonology, the interface with phonetics is the foundation of the grammar, not a peripheral issue.

So, my prediction is that debates about phenomena which straddle the fence between phonetics and phonology will increase in number and complexity, and in addition to providing descriptive subtlety, the theoretical value of detailed empirical work will also be more widely appreciated. For reasons that I will try to make clear below, however, I do not think this more scientific approach to phonology means that such debates will or should reach a settled conclusion. Consequently, my aim here is to present very general issues which I think are especially relevant to evaluating theories of the relationship between phonetics and phonology rather than to review previous work on the interface or specific phenomena.

One reason for an increasing exploitation of phonetically-oriented concepts and data by phonologists is that new, relevant, comprehensive and complex data on phenomena of long-standing interest can be obtained (with relatively little effort) directly by phonologists, in a way simply not possible a generation ago. The rate of quantitatively-based arguments in the literature does seem to be increasing. This is largely due to the ready availability of what used to be highly specialised and expensive acoustic analysis hardware and software. Now any phonologist can present

new arguments based on the type of data which may previously only have been found in the phonetic or psycholinguistic literature, though not always, it must be said, with such a reliable or rigorous methodology, and sometimes with disturbing naïveté. What is not yet changing is the preferred method of resolving disagreements about the phonological status of difficult cases such as marginal contrasts, positional allophony, parallels between morphophonemic and allophonic alternations, and parallels between continuous distributions and more categorical phonotactics. Generally, solutions propose moving the theoretical fence marking the border between the domains to shift the affiliation of the phenomenon or argue that the entire phenomenon must be moved into the other domain.

Why so? It is because our generative phonological tradition relies exclusively on discrete categories, while phonetics permits (demands!) continuously gradient and non-categorical models. When the theoretical fence is shifted “down” such that phonology is augmented (in a way that echoes Halle’s approach) in order to deal with *prima facie* “lower-level” phenomena, phonology ends up with a very large number of very small phonological categories and distinctions which do not themselves seem to be needed to express contrast or otherwise percolate upwards. Alternatively, if the remit of phonology is kept small by moving the fence “up”, focusing phonology on core “high level” phenomena such as discrete phonemic contrast, then it is phonetic theory that must be augmented. Thus incompatible solutions to the nature and location of the interface exist in the field even if there is a shared perspective that the interface rigidly fences off phonological from phonetic phenomena.

Let us pause for a moment, because metaphors of fences beg some questions. First, let’s change from the physical fence to a comparable but more abstract concept, the border. Now, instead of beginning with a simple modern political border — a line on a map representing a real but abstract boundary arbitrarily passing through and over all topographical features — think instead of a huge and (in parts) impenetrable forest of thorn trees, and the two politically independent city states which it separates. Though the existence of a border is indisputable in political and physical terms, its location as a precise line on the map (compare phonology) or on the ground (compare phonetics) is somewhat arbitrary and clearly subject to challenge. The border is an abstract expression of the categorical distinctness of the two political units, and in this case it is patently also motivated by functional/markedness factors, for the physical impenetrability of conditions on the ground has contributed to the independence of the states. Nevertheless, the jurisdiction of either city state over this or that part of the frontier forest is increasingly arbitrary and indeed fanciful, the further into or across the forest it is drawn, from either state’s point of view. The physical instantiation of the categorical political border is wide, moveable and penetrable (making it arbitrary in the fine detail of its location), and both its existence and character are explained by reference to the natural landscape. Think of the difficulties if a linear representation of this border had to be agreed diplomatically. Would it be equidistant from the (rather indeterminate) “edges” of the forest? Would it follow river valleys or watersheds? Would the stronger state claim the entire border territory as its own? Different (reasonable) ideas (compare “principles” of grammar) will compete, but no precisely located border can be an accurate interface other than in an arbitrary way, let alone explain the city states’ independence. Moreover, a focus on categorical “independence” fails to even address the undoubted partial similarities and connectedness that will be found when these two states are viewed from a wider

geo-political context. So, when talking of a linear fence-like interface, we must be aware that we are making a number of strong assumptions, most of which are so deeply embedded in the mindset of the generative linguist as to go unchallenged.

Demarcation problems within abstract synchronic grammar are dwarfed by the challenges arising from the assumption of a linear phonetics/phonology interface in acquisition, speech pathology, sociolinguistics, diachrony or other areas involving systems-comparison. For example, the diachronic emergence of phonemic contrast from previously phonetic patterns over decades or centuries tends to be modelled by phonologists as a discrete trans-generational movement of phenomena from one module to the other. While such a model permits two individuals at some point in time to differ in how they grammaticalise ambiguous input data, it does not permit either speaker's grammar to be indeterminate or flexible. Groups of speakers can be indeterminate; individuals can vary; but in the generative tradition the mental grammar of an individual cannot be non-deterministic: the grammar itself cannot fail to choose whether such-and-such a phenomenon is phonological or phonetic, let alone permit both readings simultaneously (perhaps with a statistical bias one way or the other).

In this chapter I will briefly review some competing conceptions of a discrete interface, because this is the more normal perspective, but I will also consider the possibility that phonology and phonetics overlap on cognitive and theoretical levels as well as superficially on the empirical level. The very existence of an ambiguous no-man's-land between phonetics and phonology may reflect (and be reflected by) the nondeterministic mental representations in the systems of individual speakers.

## 2 How many phonetics/phonology interfaces are there?

One highly simplified aspect of the interface that is commonly found (see below) is that phonetic stuff in all its redundancy is seen as the output of a function of phonetic "implementation" or "interpretation" to which phonological surface structures are input. More generally, this must be a bidirectional relationship between the domain of abstract and categorical relationships and entities (somehow implemented in cognitive structures within the individual, where multiple individuals possess congruent abstract systems) and the domain of gradient, continuous parameters (implemented in real space and time) which can be shared by multiple individuals via visual and acoustic modalities. Speech production and perception are realtime instantiations of the interface because they relate continuous real-time events to stored (categorical) knowledge. Phonological practice usually tries to capture just some of these aspects of the interface while being insulated from realtime psycholinguistic processing, and I too will shy away here from neurolinguistics and psycholinguistics as much as possible.

Even under such an overly limited view, phonetics and phonology can and have been defined in many and varied ways, and there are therefore many conceptions of "the" interface within the broad church of generative grammar. What I will try to do below, rather than listing and comparing these in any detail, is to try to model some of the more general underlying themes which motivate particular models, then sketch some broad families of interface types within that overview, relying heavily on other previous reviews of the literature and the interest of the reader to fill in the specifics.

One common assumption is that it is only a phonological level of representation, specifically the “surface” representation, which shares an interface with phonetics. Nevertheless, it has often been observed that aspects of phonological theory employed in all levels (whether principles, units or rules) vary in how phonetically-grounded they are. In that sense there is an “interface” for theories and theoretical constructs which deal with the phonetic underpinning of phonological theory itself. This logically separate aspect of the relationship between phonetics and phonology is somewhat tangential to the thrust of the discussion, but should not be forgotten because it is so crucial theoretically.

As mentioned, the location of the interface is intimately related to different definitions of the remit of phonology and phonetics. But other concerns also result in the inclusion or exclusion of particular classes of phenomena from the to-do lists of phonologists and phoneticians, independently of changes to the relationship of these, one to the other. This is because each area has interfaces with other grammatical and non-grammatical systems. Take phonetics for example. We all have our own unique vocal tract physiology that must be used to convey linguistic in addition to merely indexical information. Are both the concern of linguistic phonetics? Surprisingly perhaps, the answer may have a bearing on the phonetics/phonology interface. For other examples, consider the shape of the palatal arch or the ability to mimic other people’s voices. These are both generally excluded from most definitions of linguistic phonetics (though both may be relevant to the way an individual learns their language or functions as a speaker), because phonetic and phonological systems comprise abstract universals of grammar plus linguistic specifics that can be and must be learned by all speakers.

Atypical vocal tract structures or abilities are of interest however if the “idealised” speaker-hearer is understood as a member of a normal distribution rather than as a decontextualised ideal, for atypicality is part of the normal distribution. Phonetics aims to study patterns and systems in a normalised physiological/ mental setting, using evidence drawn from specific examples of learning in childhood, application in production and perception, and storage in the brain. Just like phonology, phonetics theory is interested in *systems* (of a spatiotemporal character).

Of course, since phonetic data is typically from our physical universe, embodying aspects of real space and time, phoneticians must be trained to interpret noisy real-world data. These skills make them disposed to address other physical and quantitative aspects of speaker behaviour, so non-linguistic phonetics is highly relevant to phonetic research. Phonologists’ skills, on the other hand, lead them away from phonetics towards abstract relations between contrastive units. The fields come together when phoneticians address the subset of a language which directly relates to the realisation of those abstract relations and when phonologists seek to explain aspects of the abstract patterns by reference to those self-same phonetic realisations.

### 3 A general model of the generative interface

There are three particularly useful, comprehensive and insightful collections of papers relevant to the phonetics/phonology interface, incorporating summaries and position papers by many of the major figures in the field, as well a recent review paper (Cohn in press) which touches on many of the same topics raised here, and the longer view of



Ohala (1995). These collections are Volume 18 of the Journal of Phonetics, containing the special issue on Phonetic Representation (Beckman 1990) as well as other papers (Ohala 1990; Lindblom 1990), the more recent collection Phonological Knowledge (Burton-Roberts, Carr, and Docherty 2000), and special issue in Volume 18 of Phonology (Gussenhoven and Kager 2001) on Phonetics in Phonology. Also highly relevant is the literature in the Laboratory Phonology subfield which attempts to bridge the gap between experimental phonetics and formal phonological research by recasting phonology as a quantitative science (Pierrehumbert, Beckman, and Ladd 2000), and the move to integrate these and other phonetic findings into relatively traditional generative grammar by extending the scope of the phonological apparatus (Boersma 1998; Hume and Johnson 2001; Hayes, Kirchner, and Steriade 2004). See also Fodor (1983) who I take to be broadly representative of a modular standpoint. Rather than resummaring these rich resources, I will present a very general model of the interface which may enable the reader to evaluate the overlapping and competing models more readily.

In this general model, phonetics and phonology differ in two independent dimensions which in any particular model will tend to be combined. Since different researchers attach more or less importance to one dimension or the other, it can be extremely hard to evaluate the arguments of one position against the orthogonal arguments of another.

One dimension reflects an obvious a priori motivation for the modularisation of phonology and phonetics, namely the cognitive (or social?) vs. physicalistic instantiation of sound systems. Adopting a strong position on this symbolic-physical duality means there must be an interpretative relationship between phonetics (physiological, kinematic, aerodynamic, acoustic) on the one hand and phonology (psychological, signifying, algebraic) on the other. This is a conception of the phonetics/phonology interface which Hale and Reiss (2000a: 169) call transduction, citing Pylyshyn's work in cognitive science in which generally symbol-processing cognition (and the principles underlying it) must be logically separate from the semantic issue of how the symbols relate to substance. This non-arbitrary relationship of transduction generalises over the psycholinguistic processes of speech production and perception (and, it seems to me, acquisition). In Figure 1, the horizontal dimension of dissociation between phonology and phonetics represents transduction, the relationship between substance and form. Phonetics and phonology are represented as labels for two clearly demarcated and non-overlapping domains, because whereas the former must deal with events in the physical realm, the latter must characterise abstract relationships (typically conceptualised as cognitive systems of mental representation). Hale and Reiss condemn the trend, found even in the most highly formalistic symbol-processing research, to try to incorporate findings from phonetics as functionalistic principles expressed within formal phonology, or to attempt to explain patterns of markedness from within the symbolic formalism.<sup>1</sup>

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<sup>1</sup> Despite the trend towards functionalistic "grounding" of phonology in phonetics, which Hale and Reiss criticise, dualism is strongly reflected *in practice* by the very different research cultures and methods found in experimental phonetics and theoretical phonology.

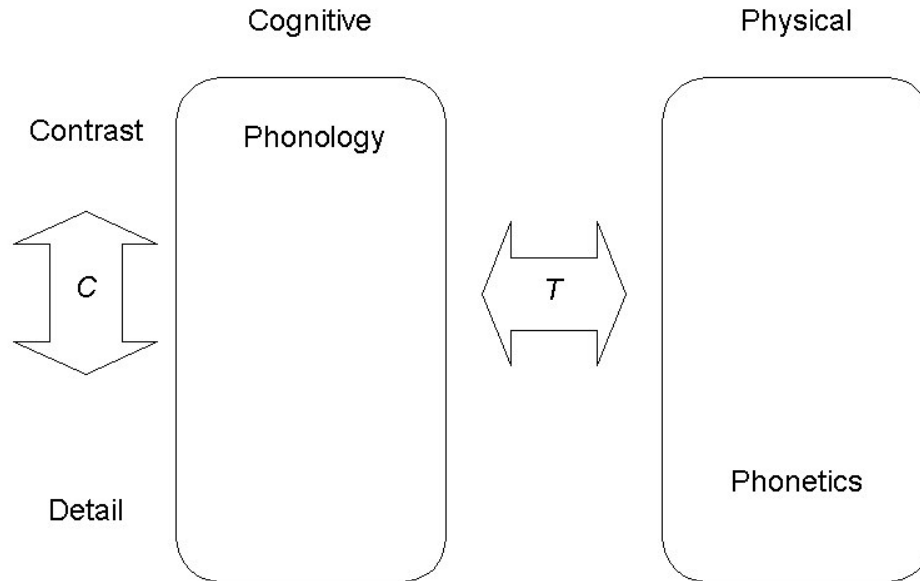


Figure 1 Interfaces: discrete transduction (T) and relative concreteness (C)

The a priori need for an interface is also justified on another set of grounds. These arguments will be presented as an independent dimension, represented vertically in Figure 1, though the fields of phonetics and phonology do actually differ in both dimensions simultaneously, which is why they are represented diagonally in the figure: but crucially I do not want to collapse the justifications for the separation of phonetics and phonology into one composite dimension. Most discussions of the interface intermingle aspects of both, paying more attention now to one and now to the other, which makes following the various positions on the interface rather difficult.

It is hard to find a term able to capture all the non-transduction differences between phonetics and phonology, but because I think most relate to the relative abstractness vs. the descriptive accuracy of grammars (i.e. the scope of the grammar and how phonetically accurate it should be), I will adapt my previous terminology (Scobbie 1997) and call the entire dimension “concreteness”.

I take it to be axiomatic that phonology, by definition, has abstract systems of lexical contrast as a central property, while phonetics relates crucially to richly redundant language in the oral-aural channel. Thus the key characteristics attributed to phonetic and phonological phenomena are not, in practice, determined by the transduction relation alone, but also by the concreteness of the respective systems.

I wish to avoid at this stage the implication that transduction must also be a relationship between detail and generalisation, but rather stress its logical independence. First, physical substance is related by transduction to all linguistic information, not just phonology. Physical media instantiate, store, embody and transmit, and they do so for semantics, discourse, abstract morphophonemic relationships, phonological contrast, fine language-specific or sociolinguistic phonetic detail, speaker-specific information etc., plus of course non-linguistic information. Second, each language user, i.e. every individual cognitive system, has to learn both phonological and phonetic aspects of their sound system, at least on most linguists’

working usage of these terms. Moreover, such an internalisation of abstract relations and the precise details needed to, say, control the speaker's own (changing) articulatory system, occur in the context of each speaker-hearer's unique genetic endowment for language, cognition and physiology. (At this stage I would like to retain the option that grammatically-learned information shades off into both the universal and the idiosyncratic, each of which will be detectable at the periphery of a grammar's system.) If it is reasonable to say that "language-specific phonetic patterns exist", then the cognitive system itself cannot by definition be free from phonetic detail, though it may be, by definition, free of substance in Hale and Reiss's sense. If aspects of both phonetics and phonology are learned, i.e. are made part of an individual's grammar, then aspects of the interface are learned too. Thus there must be a dimension of interface that does not equate to transduction, and the interface as a whole is not exhausted by the cognitive/physical interface.

I have noted above that there is little effort in contemporary phonology to solve the Concreteness Problem by defining the extent to which non-contrastive aspects of sound systems are incorporated or not into phonological theory. There is, however, one widely adopted assumption, or rule of thumb. Since phonology has the categorical phenomenon of contrast at its core, many phonological theories are couched in categorical symbol-processing formalisms. In practice, the interface is defined to occur at that level of concreteness where evidence can be found that phenomena are continuous or gradient rather than discrete and categorical. And, since concreteness is conflated with transduction, the interface is often seen as being utterly discrete.

In order to better compare and understand different approaches to phonetics and phonology and their interaction I will avoid begging the question that there is a discrete and uni-dimensional distinction between abstract, categorical phonological and concrete, gradient phonetic representations in the grammar. Given the two dimensions in Figure 1, I can keep the options open even if I assume that transduction is strictly binary at this stage (not least because I am ignoring the neurophysiological aspects of language perception, storage, and production which I think complicate this view), whereas the concreteness dimension is, *a priori*, less obviously modular in this way.

There are nevertheless two broad conceptions of the interface. It may be a crisp, clean, and principled delineation in which phonetics and phonology are modular in function and in form: a modular interface. On this view, arguments based on both transduction and concreteness will reveal the strictly modular nature of the interface.

It may be, however, that the interface is more like an overlap. The latter position would appear to have one *a priori* advantage: it would at least be able to explain why successive attempts to find the location of a modular interface have been so varied, i.e. unsuccessful! Under the overlap hypothesis, the interface combines aspects of discrete modularity with non-modularity. On this view, the interface would not really resemble the relationship between abstract political borders and actual geographical and social situations on the ground. Rather, phonology and phonetics would have a transition zone, like a tidal shore ecosystem, which is defined by its dynamic transitions between seabed and land surface. Sea and land are (like cognitive and physical domains) categorically distinct, but the tides create a habitat in its own right. The dynamic nature of tidal habitats has selected for many species which are specifically attuned to this ecosystem, even though they are closely related (i.e. in a non-categorical way) to other

land-based or sea-based flora and fauna. If we see some phonetic/phonological phenomena as being characteristic of the overlap itself, we might be able to avoid the continuing attempt to attribute them exclusively to either phonology or phonetics, a process which I think may ultimately be doomed to circularity. Overlap does not imply loss of identity: the land and the sea are not the same and neither are phonetics and phonology.

Before going on to discuss contemporary models of the interface a bit more specifically, it would be useful to very briefly explore the characteristics of phonetics and, more significantly, phonology. As might be expected, there are some core meanings for these terms which together pick out just a subset of the aspects of the sound structures of language which phonology and phonetics cover in practice. The core concerns of each domain do not even appear to touch. It is only when they are taken in broad view that they need an interface, and by then, the clarity of each discipline can get lost.

## 4 Phonology

Phonology is primarily about structured systems of lexical contrast, being a theory of how each language maintains a lexicon of tens of thousands of words by systematising the ways in which the form of each word can differ from others' forms, using a relatively small number of meaningless components which recur in different positions and combinations. For example, consider the contrast in lexical meaning signalled by the different sounds of English "big" and "hullo". Listing all such categorically-distinct lexemes is a simple and finite problem, but would not address the basic insight that each language has a system, a phonemic system, of distinctiveness. Understanding such systems is the goal of phonological research. The phonologist therefore has to present arguments as to the identity of the basic units of contrast, and their combinatorial possibilities; both universally and in a particular language. Such analyses are not simple or clear-cut, and so form the basis for numerous and fascinating theoretical and empirical debates.

Notable sub-lexical units of contrast are the segment and/or the feature. Both enable us to systematise and define "phonemic" contrast on a basic level: minimal distinctiveness involves a change in just one basic unit. For example, "big" and "pig" are a minimal pair because their differences are encoded phonologically in a single segment, and indeed in the value of a single distinctive feature. (Either is sufficient.) The featural level of analysis allows the phonologist to identify natural classes of contrast among different phonemes by reusing the same feature (let us call it /VOICE/) for different pairs of English words such as "train" and "drain", "Sue" and "zoo", or "nip" and "nib". This necessitates the postulation of the same minimal difference across different structural positions; and in different groupings of features (i.e. different segments) in the same position. These analytic steps immediately abstract away from the very different phonetic relationships between, say, stop and fricative pairs or initial and final pairs (of which more below), because patently the /VOICE/ dimension is not, and need not be, related in any simple or invariant way to phonetic parameters such as consonantal phonation. The ability to insert, link or spread features to redundant positions enables two words that differ phonologically in more than one segment in surface representation to be treated as a minimal pair.

Alternations between forms of a word or stem, if the forms are analysed as comprising different distinctive units, are also a key part of phonology even though they do not involve a change in lexical meaning. Rather, we say that a unit such as the word has systematically-conditioned phonological variants. Alternation is therefore postulated when there are some reasonable grounds for assigning different featural analyses to (a set of) words or stems in different environments. To take a simple case, the phonological environment of a following vowel seems to condition an /r/-final form of all non-high word-final or stem-final vowels in many varieties of British English. Lexemes such as “saw” alternate between an r-ful form (e.g. in “saw it”, “sawing”) and an r-less form (e.g. in “saw Kim”, “saws”). The presence vs. absence of the rhotic is typically seen as a phonological phenomenon.

More often, sub-segmental variants may be conditioned, such as the voiced and voiceless variants of the simple plural or past tense suffixes of English. It is crucial to note that only a small subset of all the variation which can be found which is treated as phonological; usually phonological status is reserved unless there are categorical changes in sound which can neutralise contrasts or feed other phonological rules. These criteria can be hard to prove, Phonetic similarity seems to be another criterion used in practice to avoid some logically possible alterations.

Allophonic variation is also a key part of phonology. It is the corollary of the claim that the same contrast or featural difference can occur at different places in structure, because the structural context has such a pervasive influence on phonetic form. (Indeed, different structural positions, as a functional consequence, have different potentials for encoding phonological systems.) For example, consider the two English pairs “tear”-“deer” and “neat”-“need”. Both pairs are typically said to exemplify the same phonological contrast, at different places in structure. But of course the phonetic instantiation of the difference between the members of each pair differs a great deal, because the stops are post-vocalic in latter case and prevocalic in the former. In most varieties of English, there will be an aspirated stop in “tear” and an unaspirated one in “deer”. In “neat”, and “need” however, other phonetic cues to the contrast apply, perhaps relating to a greater vowel duration before /d/ or glottalisation of /t/. In most phonological analyses, /t/ is encoded phonologically with identical phonological featural specifications in both words, meaning that the /t/ phoneme in English has two allophones rather than having two different /t/ phonemes, one restricted to initial position and one to final position. Instead, the linguistic systemisation of contrast results in observably different contrasts being brought in under the same set of context-independent phonological descriptors.

It is crucial to realise that the step of equating an initial phoneme  $\Phi_1$  and a final phoneme  $\Phi_2$  via an allophonic relationship does not in any way define the allophonic relationship itself to be either phonological or phonetic. This is absolutely still a matter that is open to theoretical argument and empirical investigation. If the predictable differences between  $\Phi_1$  and  $\Phi_2$  can best be handled with the theoretical machinery needed elsewhere to express phonemic contrast, then the allophony is likely to be regarded as phonological, but if some other mechanism that is never used theoretically to encode contrast is used, then the allophony is going to be called phonetic: I used this sort of argumentation myself in Scobbie (1995). Thus even when it is unarguable that  $\Phi_1$  and  $\Phi_2$  are the same phoneme it may not be clear which side of the interface specifies the differences. Is there a *phonological* specification in English in surface structure for short vs. long vowel duration; or vowel nasalization; or flapping; or

aspiration; or light vs. dark /l/; or pitch; or any other of the well-known (and lesser-known) low-level allophonies?

Alternation and allophony often interact. Consider the situation in which word-initial  $\Phi_1$  and word-final  $\Phi_2$  are accepted as allophones of the same phoneme  $\Phi$ , and a word-final consonant  $\Phi_2$  alternates between two variants  $\Phi_{2A}$  and  $\Phi_{2B}$  in conditioning environments A (pre-vocalic) and B (pre-pausal). The pre-vocalic environment in which  $\Phi_1$  is found is therefore more similar to A than B and a word-final consonant  $\Phi_{2A}$  is more likely to resemble a word-initial  $\Phi_1$  than the pre-pausal  $\Phi_{2B}$ . Does this mean that  $\Phi_1$  and  $\Phi_{2A}$  are phonologically identical or that  $\Phi_{2A}$  and  $\Phi_{2B}$  are phonologically distinct?

Even with details of the phonetic differences and/or speaker intuitions, different decisions about the phonological identity of  $\Phi_1$  and  $\Phi_{2A}$  in surface structure in such situations are possible, as we can see from the many debates in the literature. Phonological considerations vary from one school of phonology to another; phonetic considerations likewise. Simple empirical data on its own will not provide an uncontroversial answer, because  $\Phi_1$  and  $\Phi_{2A}$  cannot be phonetically *identical* (because of pervasive differences between word-initial and word-final position even in connected speech), and speaker intuitions about such situations tend to vary and/or be gradient, or influenced by orthography or sociolinguistic attitudes.

Similarly, the differences between  $\Phi_{2A}$  and  $\Phi_{2B}$  are likely to be assigned to phonetics by researchers if they are subtle variation of a type which does not seem to be found used as a major cue to contrast in other languages or contexts, or too gradient or variable to be thought of as being in the same component of grammar as phonological contrast, but such properties are in the eye of the beholder. Since phonology's irreducible goal is the analysis of contrasts and contrast-like relationships, without some additional grounds for postulating a phonological alternation between  $\Phi_{2A}$  and  $\Phi_{2B}$  on the one hand, or a phonological allophony between  $\Phi_1$  and  $\Phi_2$  on the other, the panoply of systematic relationships in the sound system (whether discovered by instrumental research or broad transcription) should probably be assumed to be phonetic unless reasons are presented as to *why* they achieve the status of phonological data. Such arguments could be the phonetic arbitrariness (i.e. un-naturalness or marked nature) of the variants or conditioning environments, similarities between the variants and demonstrably contrastive units or relationships (perhaps cross-dialectally), strong lexical conditioning, speaker intuitions of categoricalness, etc. (cf. Scobbie in preparation). Often, phonologists have also relied on their own intuitions and the categoricalness of their broad transcriptions as evidence for the phonological status of allophonic variation and alternations. Apart from this being arbitrary, even clear categoricalness is no indicator of phonologisation when contexts are categorically distinct, because the variants may differ phonetically by virtue of context alone (cf. aspiration in English).

As a result of these sorts of analytic problems, the broad consensus in phonology about many languages' core inventories and structures actually tends to gloss over some very basic problems in justifying the choice of minimal structures when two forms differ by more than one phonological feature. For example, in many varieties of English, "neat" and "need" could be argued to contrast both in vowel length and final consonant voicing. If this were the case, then they would not form a minimal pair. The problem is finessed by positing a distinctive role for /VOICE/ and a redundant

allophonic role for the vowel length difference (which may or may not be phonological, as discussed above). But the architecture of the theory, built as it is on systems of minimal contrast, demands that there is one, core, distinctive difference which is the underlying phonological difference. Difficult cases like this abound, because every phonological contrast is cued by the specification of multiple phonetic parameters. Consider varieties of English in which words like “hand” have a nasal vowel but only rarely any nasal stop phonetically: is the contrast one of oral vs. nasal vowel, or the presence vs. absence of an abstract /n/ which is not in fact observable directly? And once that decision is made about the nature of the basic phonological contrast, which of the many other phonetic differences between pairs like “had” and “hand” are to be defined as phonological, and which phonetic? These problems are both fundamental to the phonological description of any language and inherently about how phonetics and phonology interact.

Finally, it cannot be stressed too much that a great deal of research in phonology is not limited to lexical contrast. Much of this type of phonology does, however, consider the various structures, domains and relationships which provide the infrastructure for contrast, including demarcative phenomena such as stress systems. Yet other phenomena are non-lexical but quasi-contrastive, such as intonational meanings or discourse functions. These and more must be added to alternation and allophony (which are by definition non-contrastive) as phenomena central to phonological research. In each of these cases, the problem of distinguishing the phonetic from the phonological aspects of the relevant phenomena are, I think, even more problematic than in the core case of lexical contrast itself, which relies on very firm intuitions or judgements of categorical difference rather than on the weaker phonological judgements of identity or parallelism.

## 5 Phonetics

Phonetics deals with the production, transmission and perception of linguistically-relevant speech sounds, without necessarily referring to their meaning or linguistic function. Phonetic research is inclusive, however, for it does not merely constitute a negatively defined theory of those aspects of the linguistic sound system that do not signal lexical contrast. A great deal of work in the field addresses specifically the phonetics of contrast and other core phonological phenomena. Phonetic research is generally quantitative and of a general experimental character familiar to most scientists, and examines physicalistic data (whether acoustic, articulatory, neurological or perceptual) from the right-hand side of Figure 1. Nevertheless, in normal usage, a “(merely) phonetic” difference between two words indicates a narrow interpretation that this is a non-contrastive or lexically meaningless difference in sound.

The goals of phonetic theory itself overlap with the goals of phonology insofar as they attempt to explain the parameters which are used to convey contrast, the reasons for the existence or unmarked nature of particular types of contrast in particular structural positions. The two domains of inquiry therefore have a great deal in common, and in some ways it is methodology that differentiates the academic fields. Even when we consider such truly phonetic concerns such as the relationship of the physical speech production mechanism to the acoustic signal, we find an overlap in interests, because phonological distinctive features have tended to find a phonetic grounding in either the

articulatory or acoustic domain.

In this review, I will not attempt to characterise the main research goals and results of phonetics independently of their interaction with phonology, because the central topic here, the phonetics/phonology interface, is, I believe, more divisive and problematic for phonological than phonetic research.

The main point I want to make is that it is widely held that the quantitative measurement of physicalistic phonetic parameters gives rise to a picture of organically and statistically gradient phenomena. Gradient, continuous variation is indeed typical of phonetic phenomena, but care needs to be taken. A more accurate characterisation is that, if a phonetic study is either constrained very tightly so that, say, a single item in a single context from a single speaker is examined, or alternatively, if a study is based on an extremely heterogeneous set, then the results are likely to display various aspects of continuous variation. If, however, qualitative variation is introduced as a set of factors into the design of the study, then categorical effects are likely to be observed. This is obvious: qualitative changes in the materials under study can result in qualitative changes in the results. For example, measurement of the duration of a vowel in some word, say English “cat”, will typically produce a normal distribution around a mean, but if the duration of that speaker’s “bat” had been measured, the same /a/ vowel would likely have been a bit shorter because the aspiration of the /k/ in cat partially eats into the time allocated to the vowel. It is, in fact, very easy to find bimodal or multimodal distributions of values for phonetic parameters, where each mode is associated with some conditioning factor. Consequently, if we could consider all the various phonetic parameters which go together to cue some phoneme, say, in the full range of environments which can be found (some discretely distinct from others), we would not expect to find a set of unrelated unimodal continua. Rather, there would be areas of wide variation, areas of consistency, and correlations between the different parameters in the multidimensional phonetic space, so that relatively discrete clusters of values fall into constellations which would be characteristic for that phoneme. There is thus the possibility that phonetic variation is at heart partly continuous and partly discontinuous in a way that forms the basis for categorisation at a finer level than lexical contrast: i.e. that it forms the basis of phonology.

## 6 The interface from a modular perspective

Let us take it for now that phonology involves discrete mentalistic or analytic categories grounded in cognitive judgements of lexical contrast, while phonetics involves gradient and continuous categories anchored in the physical domains of speech production, acoustics etc., and that phonetic comparisons and distinctions which are not inherited from contrast at the phonological level are couched in terms of similarity in aspects of multidimensional phonetic space. Under such a view, which I think is typical of the assumptions underlying most modern Generative Linguistics, we can finally address the range of views on how these very different domains interface with each other. The main problem is reconciling the physical and cognitive biases of each field with the need to provide a model of a speaker-hearer’s internalised grammar which encodes language-specific information about phenomena which may be clearly phonological, but which may also be readily characterised as phonetic.

Within a domain-and-interface model of grammar, we typically find an organisation



based on a small number of categorically distinct modules. If the number of modules is kept small enough, this architecture does not seem impossibly unwieldy. But the number of modules may be very large, as seems to be the case given the number of sub-modular (i.e. relatively independent) theories specific to stress, to intonation, to feature theory and to constraint interaction, to perception, production, sociophonetics and phonemics. If there are sub-modules within phonology, then the number of interfaces increases, as do the number of “border disputes” with phonetics. For simplicity, I will content myself here with a bimodular view, in which most of the discussion will relate to simple segmental phenomena. The problem of the attribution of particular phenomena to one domain or the other is as great, if not greater, in other areas of interest such as intonation or stress, so the observations I make should be easy to extend.

There are a number of goals in defining the interface. One, which began this chapter, is to be able to attribute phenomena (e.g. American English /t/ and /d/ flapping, the nasalisation of vowels before nasals or a whole raft of postlexical sandhi phenomena) to either one domain or another. In such a case, the basic defining principles of one of the domains (such as categorical neutralisation of contrast or continuous gradient variation) would ideally be exemplified by the phenomenon. Many phenomena, however, seem to nearly satisfy strict criteria, while leaving some doubt, a fact that keeps the debates alive. Another goal of modularity is to explain phonologisation as the discrete movement of phonetic phenomena across the interface into phonology. Indeed, most fields of linguistics which deal with spoken language have their own reasons for distinguishing phonetic from phonological phenomena in a discrete way. This makes it possible to find cross-disciplinary evidence for the status of a phenomenon from such different fields as acquisition research or psycholinguistics, for example.

Consequently, since almost all research in phonology presupposes a rigid interface of some kind with phonetics, the field can be said to be making progress partly by revisiting the same phenomena and developing arguments about the affiliation of phenomena to one or other module, whether those arguments come from theories of language change, acquisition, or the more internal considerations of speech production or phonological theory itself.

There is a real problem, however, for some of this “progress” is entirely spurious. When familiar phenomena are considered and reconsidered, the conclusions will always be biased... when the data comes ready-categorised. The categorical bias comes from data the nature of which reflects written language, transcription, introspection about phonemic contrast, or analysis of relationships between previously established phonemic units both within and across languages. Far more useful, because it is challenging and able to test the division between phonetics and phonology from both categorical and continuous perspectives, is quantitative data: particularly *new* data. It can completely reinvigorate the descriptive basis of many phenomena, as well as provoking deeper theoretical understanding of the broader picture of linguistic sound systems. Unfortunately, broad pre-categorised transcription data is still the norm in the phonological literature even though it cannot logically be used to investigate the categorical vs. continuous nature of phenomena. Such an approach limits the purview of phonology arbitrarily to easily-observable and transcribable phenomena. On the other hand, distributional patterns within quantitative phonetic data can be examined and distinct centres of gravity proposed as the instantiation of phonological categories, or quantitative speaker intuitions about

well-formedness can be undertaken which can then identify strong categorical patterns as well as weaker ones. Such an approach gives just as much room for debate and argument as exists presently, but it would be well-informed debate.

We should not expect unrealistic standards of proof of phonological categorisation from quantitative data. When a few minor phonetic parameters or speaker uncertainties are found which suggest that a well-known neutralisation, say, is subtly incomplete, we must not simply reject the insights of previous generations of researchers without further consideration (a point made strongly by Manaster-Ramer 1996a; 1996b). Evidence of subtle deviations from categorical behaviour is not the same as evidence of completely non-categorical behaviour. If it proves impossible to square new data with old phonological models, the fault may lie in the models, rather than in the insights of previous descriptive research. Our models may have to change to encode nearly-categorical procedures, operations, and indeed fuzzy categories themselves without giving up the insight that core phonological phenomena are, at heart, *not* smoothly gradient and continuous.

Let me briefly turn now to a few specific examples of proposals of the nature of the interface, offered not as an exhaustive list, but to illustrate some of the variety which can be found.

### **6.1 Language-specific phonology, universal phonetics**

The influential work of Chomsky and Halle (1968) stands as an example of an interface with an apparently clear definition. The “output” of the phonological module, i.e. the specification which interfaces with phonetics, is a cognitive representation of language-specific information. Once universal phonetic detail is added, the transduction-interface can be the same in every language. This proposal expands phonology downwards a bit: the formal phonological mechanism necessary for contrast would be used to express all language-specific sound system generalisations from the most phonetic-like to the most morphophonemic.

It is unclear to me whether the phonetics/phonology interface in a transduction sense coincides with the interface conceived of as the boundary between the language-specific and the universal. The idea that all language-specifics belong to “phonology” makes it easy to draw parallels between language-specific phonetic and (morpho)phonological phenomena within the grammar. However, the interface faces a new set of boundary-disputes revolving around the language-specificness of particular phenomena. Moreover, the categorical formal mechanism, developed for lexical contrast, was not up to the task of encoding all the gradient minutiae that we now know to be part of what must be learnt when a language is acquired (Keating 1985). In terms of Figure 1, the interface here is drawn quite high, and so very low-level but language specific phonetic phenomena have no real home. They belong neither with universal phonetics nor high-level categorical phonology.

### **6.2 Language-specific interpretation**

Phonetic “interpretation” introduces language-specific phonetics via, it seems, transduction. There is categorical discrete phonology on the cognitive hand and continuous phonetics in space-time on the other, with quantitative numerical functions to mediate between them (e.g. Keating 1984; Pierrehumbert and Beckman 1998;

Keating 1990; Cohn 1990; Pierrehumbert 1990; Silverman 1997; Cho, Jun, and Ladefoged 2002). Consequently, such models are phonetically-detailed, but add the detail as part of a model of transduction using continuous mathematics, not in phonological representations. The finest-grained language-specific detail exists only in the real physical world as an exponent of the abstract structures. In fact, even quite high-level aspects of sound structures can be left unspecified in the grammar for distinctive features, because the transductional interpretation is itself language-specific, and is able to mediate between categorical and continuous aspects of the system. On this view, the interface is both part of the grammar, and yet distinct from the formalism required to capture core phonological phenomena, with the result that the phonology can be relatively abstract and categorical.

Much research work (especially in the Laboratory Phonology tradition) seems to follow the basic method of looking for the quantitative relationship between real phonetic data and categorical phonological structures which this approach requires. There tends to be a balance between empirical and theoretical aspects which makes for a pleasing symmetry, but the need for quantitative data has tended to restrict the appeal of this approach.

## 7 The interface from a non-modular perspective

An alternative to dealing with low-level language-specific phonetics along the dimension of transduction is to combine highly concrete representations with other aspects of phonology, so that the dimension of concreteness is explored.

### 7.1 “Phonology” all the way down

The categorical machinery used to encode contrast and other core phonological concepts can be augmented so that all language-specific detail, quantised into small enough units, is expressed within one formalism. The granularity can get to be really very fine-grained indeed, and, as was noted above, the smaller and more numerous the categories are, the less categorical they are relative to phonemic contrast. Thus there are aspects of chunky gradience and continuousness in these theories, though at heart they share the same discrete category-based architecture that is essential for contrast: different levels of granularity capture different phenomena.

Putting language-specific fine-detail in the grammar brings the interface, and hence phonology, right down Figure 1 towards concreteness. It's not clear if all language-specifics are incorporated. On the transduction dimension of the interface, these highly concrete and representationally-rich phonologies still seem to maintain a strict demarcation between the generative grammar and physicalistic phonetics, but this is a point of contention. Hale and Reiss (2000a; 2000b) criticise such phonology as being rich in phonetic substance, but perhaps it is richness of detail which represents substance rather than substance itself.

There are a number of approaches which I think can be roughly grouped together as being phonology stretched all the way down to make a unified non-modular framework (e.g. Boersma 1998; Flemming 2001; Steriade 2004). Moreover, some of this work represents also an approach in which the phonetic grounding of phonological patterns (including the parallelisms between phonetic and phonological

phenomena first brought to general attention by Halle) and functional considerations of speaker effort and perceptibility are central concerns (Silverman 1997; Hume and Johnson 2001; the papers in Hayes et al. 2004; Kirchner 1998). In language, there seems to be a set of functional pressures to maintain contrast, to favour more perceptible contrast, and to reduce articulatory effort, for example. In non-modular theories, these functional tendencies (presumably universal) are incorporated into the grammatical formalism (including representational units and computational processes) along with substance-free phonological principles and operations. Such functional approaches vary in the extent to which representations are phonetically-detailed. Some make it possible to specify fine detail and hence derive very concrete surface representation; others use phonetic tendencies to control the distribution of very high-level categories. Just as highly detailed phonological representations are not actually phonetics (because there is no transduction) despite being *more* phonetic than less-specific ones, the functional principles are not truly phonetic, for the same reason, despite being *more* phonetic than many phonological principles. These phonological codification of phonetic detail and phonetic tendencies cannot replace true phonetics by being integrated into a cognitive, symbolic phonological module.

## 7.2 “Phonetics” all the way up

Articulatory Phonology (e.g. Browman and Goldstein 2004) provides a very different kind of unified model which tends to be even richer in fine-grained detail than the concrete models of the preceding section. This and related models display their phonetic origins in their structural and theoretical organisation just as those in the previous section display their phonological antecedents.

Articulatory Phonology has been extremely successful for researching phenomena relevant to the phonetics/phonology interface. Its spatio-temporal, time-aligned and internally dynamic articulatory gestures can be subject to subtle and fine-grained realignment, or changes in amplitude, which are ideally suited to explaining some sorts of variation in output, including acoustically categorical ones. Many phenomena which previously were assumed to be categorical processes of insertion, deletion, assimilation or reduction have been shown instead to result from particular instantiations of continuous relationships between gestures (e.g. Browman and Goldstein 1995; e.g. Zsiga 1997). Like the research into functional explanations for phonemic patterns in §7.1, this research has spanned phonetics and phonology and led to a greater understanding of their interaction, though in this case the formalism generally has a far more phonetic flavour. The major difficulty with Articulatory Phonology is seeing how it deals with core phonological phenomena with all their categoricity, and how to abstract away from the specific information in its representations.

In terms of the tidal zone analogy, Articulatory Phonology is like a sea creature specialised to explore up to around the high water mark, whereas the functional phonologies are like a wading bird whose domain extends down to around the low water mark. Articulatory Phonology and the functional phonologies reflect their antecedents so very clearly that it is hard to ignore their different origins. Thus their theoretical and descriptive interests overlap, but extend in opposite directions. Ohala (1995) is surely right when he says that views of the interface reflect the primary interest of the viewer.

## 8 Quasimodularity

### 8.1 From continuum towards overlap

Ohala is in fact a longstanding advocate of non-modularised phonetics and phonology (e.g. Ohala 1990; 1995). His own interests extend well beyond the specification of all and only the well-formed outputs of a synchronic grammar, which may explain why he has so consistently stressed the continuity of phonetics and phonology for so long, and the role of phonetics as the source of explanation for some phonological patterning and change. But this does not mean that phonetic naturalness plays any actual role in speakers' grammars. His stance is that grammar is capable of encoding whatever it finds, by and large, but the "by-and-large" functional effects (of all sorts) tend over time to change languages, presumably from one phonetically relatively natural state to another.

For Ohala, functional processes occur primarily in interactions between speakers, not within a single speaker's own grammar. He is also well aware that phonology is not always natural (Anderson 1981) despite being oriented towards natural phonetic patterning, because incompatible phonetic functional tendencies are in competition with each other, and also with phonological tendencies. Successive generations are able to transmit patterns that become increasingly un-natural in some regard as the natural phonetic cause is lost of a contrast or paradigm which itself is maintained phonologically. Thus patterns arise that contradict one set of functional tendencies, perhaps initially in a minor way, as a consequence of the speaker-learner paying greater heed to other sets. Ultimately only a diachronic explanation for the language's patterns will satisfy, and a synchronic battle between different functional constraints within the phonological grammar is rejected. This is an approach in which modularity of some sort is inherent, despite Ohala's view that there is no interface between phonetics and phonology. His perspective on this issue may be in relation to generative grammar.

For Ohala, phonology poses the questions, phonetics provides some of the answers, and our ability to learn abstract patterns (which provides the mechanism for creating tension between the two) provides the rest. (See also Vihman's work, mentioned briefly below.) It is thus more appropriate, I think, to define his work as being "quasimodular", a perspective with which I conclude.

### 8.2 Phonetics and Phonology are not the same thing

Some approaches to phonetics and phonology being by stressing parallels between the two domains (e.g. assimilation is like coarticulation). While such parallels are extremely important to understanding the interface, it must not be forgotten that at the limits, the core of phonology has no parallel in phonetics: contrast and patterns of contrast are different in kind from sounds and patterns of sounds. Phonological differences can and have been very successfully studied without a great deal of phonetic sophistication. They are, to an extent, open to analysis through introspection of the distribution of other high level phenomena. Phonological contrasts are even amenable to expression in other media, such as in alphabetic writing systems. This is why the existence of an independent phonological module is repeatedly defended.

For a familiar example, consider the phonemes that condition the distinct allomorphs of the past tense or plural suffixes in English. The facts of the distribution are not established in the synchronic grammar on phonetic grounds but primarily through facts of contrast and analytic identity. Yes, the “natural” classes of /VOICED/, /VOICELESS/ and /STRIDENT/ and the distributional restriction on /GEMINATION/ which dictate “baths”, “lounges” and “groves”, or “chapped”, “chatted” and “hummed” can be explained by reference to phonetic facts of production and perceptibility, but they do not need to be identified through phonetic analysis. In fact, it is not clear that they could be found on a purely phonetic basis without the help of top-down information. This is why these and other non-natural classes can, and have been, found through phonological analysis, and why phonological patterns persist well past their phonetic sell-by date.

Nor do even the most natural of classes have to have a particular phonetic exponent: the same phonological classes can, of course, exist for speakers with different accents. Consider the wealth of phonetic differences that variationist research can reveal even within what is often thought of in linguistics as a single dialect. Some speakers of Scottish English, use completely devoiced final /VOICED/ obstruents, but phonetic differences in how /s/, /f/, /t/ differ from /z/, /v/ or /d/ do not alter the choice of allomorph. (Though such shifts in phonetics may lead diachronically to phonological reanalysis.) The phonetics of a phonological class is a compromise between different functional pressures. It will be, however, largely high-level categorical alternations, phonotactics, phonologically-conditioned morphology and the shared lexicon which determine the membership of such a class at any synchronic point.

But, though appearing to hold relatively steady (rejecting merger or split), as the phonetic exponents of phonological categories smear diachronically, cross-dialectally or stylistically across phonetic space, changes to the phonological system do occur. A strictly modular grammar would permit these patterns to be phonetically gradual but phonologically discrete, but this is not the only logical possibility. The phonological changes might themselves be gradual. As the phonetic underpinnings of the phonological categories shift from one balanced set of cues into another (perhaps by reweighting the cues or changing the set), so the contrastiveness of individual words, or phonological classes of words, could be gradually attenuated. If so, the interface between what seem to be distinctly phonological and phonetic systems has to be flexible.

So it seems that we do need two domains, the phonological and the phonetic, fairly traditionally-drawn; but it is precisely the nature of their interface for which we need a new set of theoretical ideas if we are to make progress. One view, which I feel drawn to, is that they form module-like domains that are not completely distinct in that they share a middle ground. This is interface as overlap. Alternatives are that they form the ends of a continuum (interface as transition) or two discrete and distinct modules (interface as interpretation). These alternatives have been represented for some time, by a number of approaches, some of which have been cited above. What has been and still is lacking, however, is a formal theory of overlap. How can we have relatively crisp categories such as those established through phonological contrastive analysis co-existing with gradient phonetics; and how can cognitive and physical domains be only quasi-distinct?

One way may be through a framework in which *both* transduction and concreteness

are continuous rather than discrete, but where the phonetic and phonological ends of the continuum are nevertheless characterized by continuousness and categoricalness respectively. The trick would then be to have an interface between them which was in some respects continuous (gradience would give way slowly to categoricalness, and vice versa), and in some ways not (it being possible, if not necessary, to take a perspective in which intermediate cases belong to one domain more than the other). Thinking back to the tidal ecosystem, the overlap could be temporary home to truly phonological and truly phonetic phenomena, as well as providing a home for intermediate, transitional and ambiguous ones. This is a model in which the language user's grammar can be flexible, non-deterministic and gradient about modularity.

### **8.3 Exemplars**

Such a model seems to be being developed by those working in a probabilistic framework sometimes called Exemplar Theory (Bybee 2001; Pierrehumbert 2001; 2002; 2003; Coleman 2002; Silverman 2004; Bybee and Hopper 2002). This work integrates phonological patterning and phonetic detail by looking at how generalizations and abstractions emerge statistically from raw distributional patterns, and how the patterns themselves may have functional explanations. This chapter has been greatly influenced and stimulated by that work and more cited therein, and in many respects this chapter is my way of working through the very radical proposals which they contain in an attempt to understand how they fit with the more familiar linguistic traditions that are also a strong influence on current theory and on my own ideas.

Exemplar Theory draws on psycholinguistic “multiple-trace” models of the mental lexicon (e.g. Goldinger 1997; Mullenix 1997; Pisoni 1997; Johnson 1997). (The terms seem to be interchangeable.) In these models, the fact that learnt language is a type of memory is central, and the physicality of phonetics and phonology is extended from models of speech production into neurolinguistic models of storage, planning and perception. Multiple detailed exemplars or traces of every lexeme are stored: but in storing such an enormous number of only subtly-different tokens of real world productions, abstraction and coalescence occur by necessity. This happens automatically by virtue of encountering “different” tokens of the “same” word. Memories are contextualised to the situation of use, so sound patterns are associated or labelled with a contextual meaning. Actually, the immediate context of utterance is so rich that the range of meanings is huge, but only recurring sound-meaning pairings are strengthened. The abstractions that are formed must be much like traditional distinctive features and phonological units, forming a hugely complex, partially hierarchical web of associations. The lexicon, as it is acquired, becomes a mix of structured abstractions and detailed memories of previous speech events and contexts. Probability distributions over phone or lexeme sized categories are automatic (since more frequent tokens and categories are represented more frequently), so the theory has been used to explain frequency-effects in phonological patterning and to model the gradience of judgements of phonotactic well-formedness.

In such a model, transduction is less relevant to the interface because the initial cognitive representations of speech sound and articulation are so highly-detailed, well-beyond the levels needed to encode any linguistic contrast, somewhat like a high fidelity recording. There is of course transduction during perception and production, and yes it is likely to be relevant to phonology, but not in the same way as the far more

extreme separation dividing abstract phonology from substance.

Memorisation of such enormous quantities of so-subtly varying detail in the repetition of a given word over long periods of time cannot be maintained, and the ways in which a trace blurs into others in memory reinforces semantic links with lexical meaning, phonological categories, etc., as well as speaker-identity, mood, paralinguistic and social aspects of language use and so on. The pairing of sound and meaning exists for any continuum or set of categories arising from speech, so long as the speech “sounds likes” an example of a category or a region on a continuum, more or less. Individual exemplars form parts of many distributions in the many dimensions of phonetic space. Input automatically appears in this space in relationship to previously-encountered input. The power of lexical contrast is that despite phonetic variation, “pin” and “bin” are semantically extremely disjoint, and once the lexical identity of a trace is known, the rich phonetic detail, however subtly-distinct from other traces, can be viewed through a categorising lens.

If unfamiliar lexis, voices or accents are encountered, new traces are formed which overlap less with previous distributions and may, if they are initially disjoint enough or if additional tokens reinforce them, form new distributional modes and loci. Categorical, semi-categorical or non-categorical intuitions about patterns usually modularised into sociolinguistics, orthography, phonology, paralinguistics, and morphophonemics are all available for introspection, as is awareness of articulatory or acoustic detail. In this sort of model, a broader conception of phonology is natural: intuitions about other people’s sound systems are as naturally explicable as intuitions about one’s own.

All categories, including phonological ones, emerge as probability densities in distribution of tokens in a multidimensional phonetic map. For example, in Figure 2 (based on a figure in Pierrehumbert and Gross 2003) there is a highly simplified map of continuous phonetic space (in only two dimensions). Each individual trace (of lexical items, say) is actually encoded in so many dimensions that the distributions in just two may be viewed as being normalized for the other differences, so that vowel duration distributions are not muddled by the effects of vowel height, for example. In Figure 2 are two fairly clear categories, one lower to the left, and one to the right. The distribution partitions the space fairly clearly into two parts. These may correspond to classes of lexical items differing in their vowel, i.e. correspond to a contrast. They may indicate a relatively primary cue (e.g. to a phonemic vowel contrast), or a more minor one (e.g. to the post-vocalic voicing contrast), depending on the density and unambiguousness of the cluster and how it interacts with more or less gradient distributions along other dimensions that are not shown. Continuous phenomena can also be labeled, and, as indicated above, labels can encode not merely lexical meaning but all sorts of contextual meaning, such as sociolinguistic or paralinguistic information.



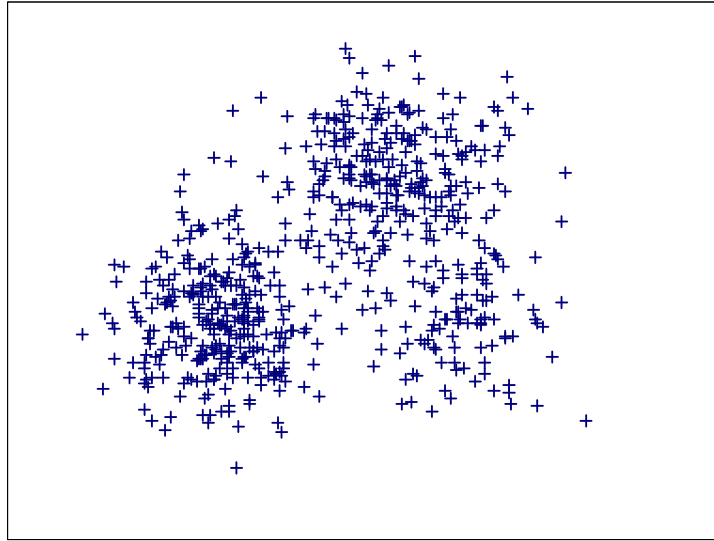


Figure 2 Sample phonetic distribution in two arbitrary dimensions

Note that there is also a minor distributional split between the upper and lower distribution on the right. This split may function in the same way as the major split (i.e. arise for the same sorts of reasons), but its existence as a category is less clear-cut. In this way, the difference between categorical and non-categorical is itself gradient. The question of whether there are two or three modes in Figure 2 does not have a clear answer. It is in this way that the sort of “difficult” interface phenomena referred to above need not be attributed to either one module or the other, but can be indeterminate and ambiguous. Categorically-distinct labels on some of these datapoints could enable clear categorisation in one sense, but how reliably those differences are conveyed depends on their whereabouts in the phonetic space.

Such a model is compatible with language learners forging their own phonological and phonetic systems, under the influence of phonetic and phonological patterns in the input and our cognitive-linguistic predispositions (Vihman and Velleman 2000). Indeed, a great deal of support for the overlap model is likely to come from work which, like Vihman’s, charts the emergence of categorization by the child. It is not compatible with universal phonological features or the sort of strict modular separation discussed above in which phonology *cannot* be influenced by phonetics. Rather, high level phonological generalizations will tend not to be influenced, but phonetically weaker, less frequent, less categorical, more variable patterns will indeed be more contingent on actual phonetic substance. Within higher-level phonology itself it has always been understood that in addition to the clear categories, there are others whose status is more problematic. Especially difficult for traditional approaches are highly limited phonotactics, complex morphophonemics and suppletion. Furthermore, every phonological system has a periphery of dubious candidates, (especially those with limited lexical distribution, e.g. in loan words or names) and it may be that these reflect either clear phonetic modes with little systematic generality, phonetically weak modes, or both.

These properties of the model are advantageous in capturing interface cases in which there is evidence clear phonological categorisation but phonetic non-determinism, or phonetic consistency with indeterminate phonologisation. I am drawn to the model

because of evidence that we can acquire the contrasts and system of our speech community with some degree of flexibility (and in a bottom-up, category-forming way, cf. Vihman & Velleman, 2000). For an example, in a study of a group of 12 Shetlandic adults (Scobbie in press), I found that the individuals' VOT targets for /p/ (and the distribution of tokens) provided no evidence that each individual was limited by universal grammar to learning either a short lag or a long lag target for /p/ (the traditional dialect form [p] or Standard English [p<sup>h</sup>].) Interspeaker variation was wide-ranging and continuous: some produced a unimodal distribution between the two "universal" short and long lag targets. Nevertheless, when all the data is pooled, the general functional tendency towards stops being either short lag or long lag does seem to be clearly discernable (Figure 3). Markedness is evident from the group behaviour, but not necessarily in individual behaviour; just what we might expect from Ohala's work.

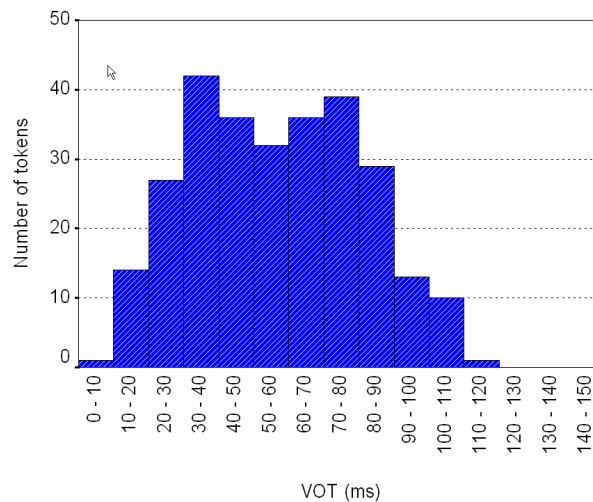


Figure 3 Histogram of VOT for /p/ from twelve unimodal Shetlanders: a distribution in one phonetic dimension with two phonological modes

Exemplar theory does not demand that one feature or another is distinctive. So the same lexical items can be distributionally distinct in different dialects of a language, but the locations of the phonetic distributional modes will differ. And one dialect's distribution of tokens may be more or less distinct from the general background or other local peaks than the other dialect, automatically meaning that different contrasts can be more or less robust.

Finally, it was mentioned above that the Exemplar model raises an interesting possibility that the transduction dimension is also quasi-modular. Since the model is based on multiple cognitive traces which directly encode phonetic detail, far beyond what will eventually be necessary for the sound system, the distinction between cognitive and physical is broken down somewhat (Figure 4). This raises very interesting possibilities for research in language acquisition (cf. Vihman's work on phonetics and phonology) and speech pathology (cf. Perkins 2005 and references and papers therein on comparable developments on pragmatics), two fields in which the cognitive linguistic aspects of the system interact with physical and/or non-linguistic aspects.

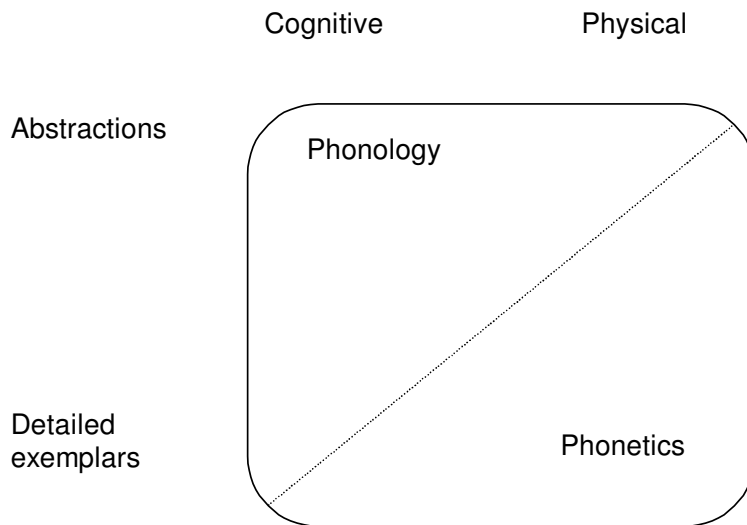


Figure 4 Model of non-modular phonetic and phonological space

Phonetics and phonology still differ in two dimensions, but exemplars are so detailed that, like a compressed digital recording, they merely transpose relevant aspects of an acoustic waveform to neural storage to enable a relatively faithful trace of the input. This may only be short-term storage, which will excite and reinforce certain previously- stored abstractions and pathways, but long term mental representation of language is also, in this theory, biased towards being as highly concrete as it can be. The physical/cognitive distinction therefore does not seem so relevant to phonology as it does when dealing with a discrete and crisp mapping between such higher-level units as distinctive features and phonetic stuff.

In general this seems a beneficial situation, because phonetic substance, after all, requires *multiple* transductions, for it is acoustic, and aerodynamic, and articulatory, where one is caused by the next. The articulations themselves result from motor planning, and the motor plans are themselves stored neurologically as exemplars of productions. When, in this process of transforming a memory into a movement, does the speaker discretely transform the cognitive into the physical? And how great is the linguistic role of transduction in perception, a complex process of many facets which has to separate and analyse information in parallel, such as the lexical content of input and its indexical, discourse and paralinguistic content, and use top-down semantic, pragmatic and lexical frequency information (stored neurologically and obtained from other perceptual senses) in addition to detailed mental representations of phonetic substance.

## 9 Conclusions

Phonology is widely accepted as a linguistic module (in the sense of Fodor 1983), and phonetics too, to a lesser extent, though this must not be taken to imply that there is agreement as to how to define either domain, let alone their interface. In this chapter I have indicated some of the key characteristics which support the separation of phonetics and phonology into distinct domains — conceptual, descriptive and

methodological — while keeping the issue of strict modularity open for discussion. I have reviewed some of the basic approaches to the interface between phonetics and phonology within the modular tradition, which pits phonology against phonetics in a theoretical battle over a tranche of interface phenomena. We have also seen there is an approach which is non-modular in practice, in which the two domains fall on a continuum with a single underlying theoretical architecture linking them. By their very nature, such non-modular frameworks are most successful when dealing with intermediate phenomena, because they can readily encode parallels with slightly higher or lower level phenomena. Even so, there seems to be little support for the position that phonology and phonetics are one and the same, for the traditional core characteristics of phonology and phonetics remain distinct. There must be an interface of some description even in non-modular approaches. It could be a portion of the continuum, or, as I have suggested, a competitive area of descriptive and explanatory overlap.

There is a general consensus in linguistics that there must somehow be a clear definition of “the” interface (though what, or where, it actually *is* varies widely) because phonology has at its core the study of an irreducibly cognitive and categorical phenomenon, namely contrast, while phonetics has as its core the study of the continuous physical media of speech production and perception. As indicated above, I think it important to distinguish the dualistic separation of physical and mental domains from the question of how phonetically-concrete the grammar of the cognitive system should be. This seems particularly useful when trying to understand different research traditions. It is also essential to recognise that even though there are clear differences between the core aspects of phonetics and phonology, this does not mean there needs to be a clear phonetics/phonology interface.

Generative phonological theories must address the concreteness aspect of the interface: to what extent are the formal representations and operations required for core aspects of phonology used to encode (even just language-specific) fine phonetic detail? In each descriptive grammar the parochial instantiation of this concreteness problem is: which (parts of which) phenomena require phonological analysis? For theoretical phonology generally: *what* counts as data and *why*? These are fundamental interface issues for surface-oriented phonology because they delimit the lower limit of the field by defining the very data which must be, or need not be, described and explained. In Exemplar theories, however, whether a given phenomenon is strongly categorical or not may be speaker-dependent, context-dependent or otherwise a matter of degree, and a clear answer as to whether a given phenomenon is or is not phonological is not possible. The data relevant to such frameworks is far more inclusive, giving phonology in a broader sense a role beyond its traditional modular limits. To address such new perspectives, indeed even to evaluate the traditional approaches to the interface and make progress in the debate on the fundamental phonetic nature of phonology itself, detailed quantitative research methods must be employed both phonetic and phonological.

The transduction aspect of the interface struggles with how (non-contrastive language-specific) physical differences come to be represented cognitively, and how functional phonetics can explain phonological tendencies. However, when the cognitive dimension of language becomes highly concrete, as detailed as is necessary to represent the relevant physical reality, perhaps this moves functional explanations across the transductional divide, whether in a discrete modular way, or more gradually.

It is not clear to me what this means in practice, except that functional *explanation* for phonological patterns in general is very different to codifications of specific, often un-natural phonological patterns. Moreover, the most natural patterns and tendencies found in a language's sound system are likely to be regarded not as phonological at all, displaying as they do many of the traditional characteristics of phonetic patterns. Thus fundamental phonological problems (e.g. inventory size and membership) which seem to be amenable to functional explanation still demand a transductional separation of domains to make conceptual sense.

I think that the most exciting prospect for progress may come from models which blur both dimensions for a number of reasons. First, modular and generative theories set themselves the task of *solving* the interface problem, and so far have not merely failed to reach any long-lasting consensus, but, by relying on pre-categorised data have sometimes been so descriptively inadequate as to be theoretically misleading: the claimed categoricalness of many external sandhi assimilations in English being a good example. Second, individuals (and groups) can vary both subtly and radically in language acquisition, structure, use and pathology, suggesting that models based on non-determinism and variable systemisation could enable more realistic insights into sound structure. Flexibility may be modeled by allowing a continuum from categorical to continuous phonetic distributions, by maintaining distinct theoretical principles of core phonology and phonetics, and letting them compete and simultaneously account for (parts of) ambiguous phenomena. If a complex phenomenon turns out to have predominately phonological characteristics in some contexts but predominately phonetic in others, then our theoretical models should reflect this, and be forced neither to choose one domain over the other nor to characterize the phenomenon (which will always be fuzzily defined to some extent) as being cleanly "split" down the middle.

A quasimodular framework rejects the widespread assumption among phonologists that "categorical" and "gradient" are themselves discretely distinct (see Cohn in press for an excellent discussion). Choosing "meta-gradiance" does not mean there are no clear phonological categories, but not-so-clear categories also exist, and the whole framework rests on some sort of a statistical foundation from which units and categories can emerge (for a specific proposal, see Pierrehumbert 2003) rather than discrete and substance-free symbols. Strong categories are clear modes in the distribution of values in multi-dimensional phonetic space. Phonetic space is not a flat equilibrium, but a highly complex distribution which successfully communicates linguistic structure from one speaker to another. All language-specific information is there in the phonetics to be learnt, but some modes are bigger, crisper, and stand out from the background more than others.

The recent results that have motivated Exemplar approaches involve interaction between idiolectal phonetics and the phonetics of contrast: somehow the characteristics of individual speakers can be stored and processed along with phonological and lexical information. It seems therefore that the interface should be dynamic, ambiguous and soft on the one hand, but without denying that the categorical characteristics of lexical contrast are very different from the continuous nature of sociolinguistic and idiolectal variation in the phonetic realization of such systems.

Though the assumption that there is a strict interface has prompted a great deal of research, some of it of lasting value, it is not an assumption which is logically

necessary. Nor is it one which is useful to many researchers looking precisely at those phenomena whose affiliation is unclear. Further, it does not provide a safe and non-circular basis for demarcating the body of data which phonological or phonetic theory attempts to explain. And finally, assuming there is a strict interface does not seem to limit particularly the variety of ways in which *core* phonology can be approached! On the other hand, the view that phonetics and phonology differ but overlap predicts that difficulties of demarcation and identity exist as part of an individual language user's mental grammar, thus prompting new questions, models and solutions to old analytic problems of language structure, acquisition, change and use. The ebb and flow of different theoretical conceptions of the relationship between phonetics and phonology may be explained ultimately by the flexible nature of the interface itself.

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